THE GEOMORPHOLOGY OF THE UPPER DARLING RIVER SYSTEM WITH SPECIAL REFERENCE TO THE PRESENT FLUVIAL SYSTEM

By S. J. RILEY[1] AND GRAHAM TAYLOR[2]

ABSTRACT: Five distinct regions are evident in the Upper Darling River System, namely, the eastern hill lands, the western alluvial plain, the Barwon dominated region, the Pilliga sand plain and the Lightning Ridge region. Two thirds of the total area of 300,000 km² is dominated by alluvial deposits and direct river action.

Stream morphology and regime change dramatically in the transition from the hill lands to the plains. Distributary patterns dominate the plains. Sediment load of streams on the plain is wash load. The plains are aggrading at an average rate of 2×10^{-2} mm/yr and, in the eastern areas, have a definite alluvial fan morphology.

Stream gradients across the plains are of the order of 5×10^{-5}. Channels are sinuous, narrow and have low width-depth ratios. Bench development is active.

Paleo-channel sedimentology and morphology suggest fluvial regimes different from those of today. However, the difference in regimes need not be related to climatic or tectonic change. Changes in fluvial regimes can be associated with the progressive degradational-aggradational development of the fluvial system under constant external conditions.

INTRODUCTION

Although the upper Darling River basin has been settled since the 1850s (Jeans 1973), little in the way of scientific study of the streams has been done in the area as a whole or on the river system which has been and is increasingly important to the area. With the exception of stream flow and climatic records, little is known of the area in terms of present-day geomorphic processes or of the genesis of the landscape.

This paper discusses recent advances in the study of the area, particularly with respect to the morphology and sedimentation of the Darling River in the area east of Brewarrina.

The authors would like to point out that, because there is so little information in the area, there is much scope for speculative thinking. As a consequence they do not entirely agree, on all the points presented herein. However, they have endeavoured to present the many facets of each argument as fairly as they can.

THE CATCHMENT

The Darling-Barwon River upstream of Brewarrina has a catchment area of 300,000 km² (Fig. 1). With the exception of several small south-flowing streams between Walgett and Brewarrina the major tributaries originate in the eastern highlands.

The eastern region of the catchment, approximately one-third of the upper Darling system, is distinguished by low to high-relief (up to 1,000 m) hill land topography. The remainder of the catchment is relatively flat (relief less than 300 m). The eastern third is composed of Palaeozoic sandstones, shales, intermediate to acid volcanics, granites, and Cainozoic basalts which crop out in many places or are covered with a relatively thin veneer of colluvial/alluvial material. The remaining two-thirds of the catchment are, on the whole, covered with Quaternary and older alluvium. There is some aeolin surficial cover in the northwest of the catchment.

The area of fluvial deposition extends westwards from the western margin of the eastern highlands. Surface gradients in the alluvial plains range from 10^{-4} near Moree to 10^{-5} near Brewarrina.

The catchment can be subdivided into five major physiographic regions:

1. The eastern hill lands.

1. School of Earth Sciences, Macquarie University, North Ryde, N.S.W. 2113.
2. School of Applied Science, Canberra College of Advanced Education, Canberra, A.C.T. 2616.

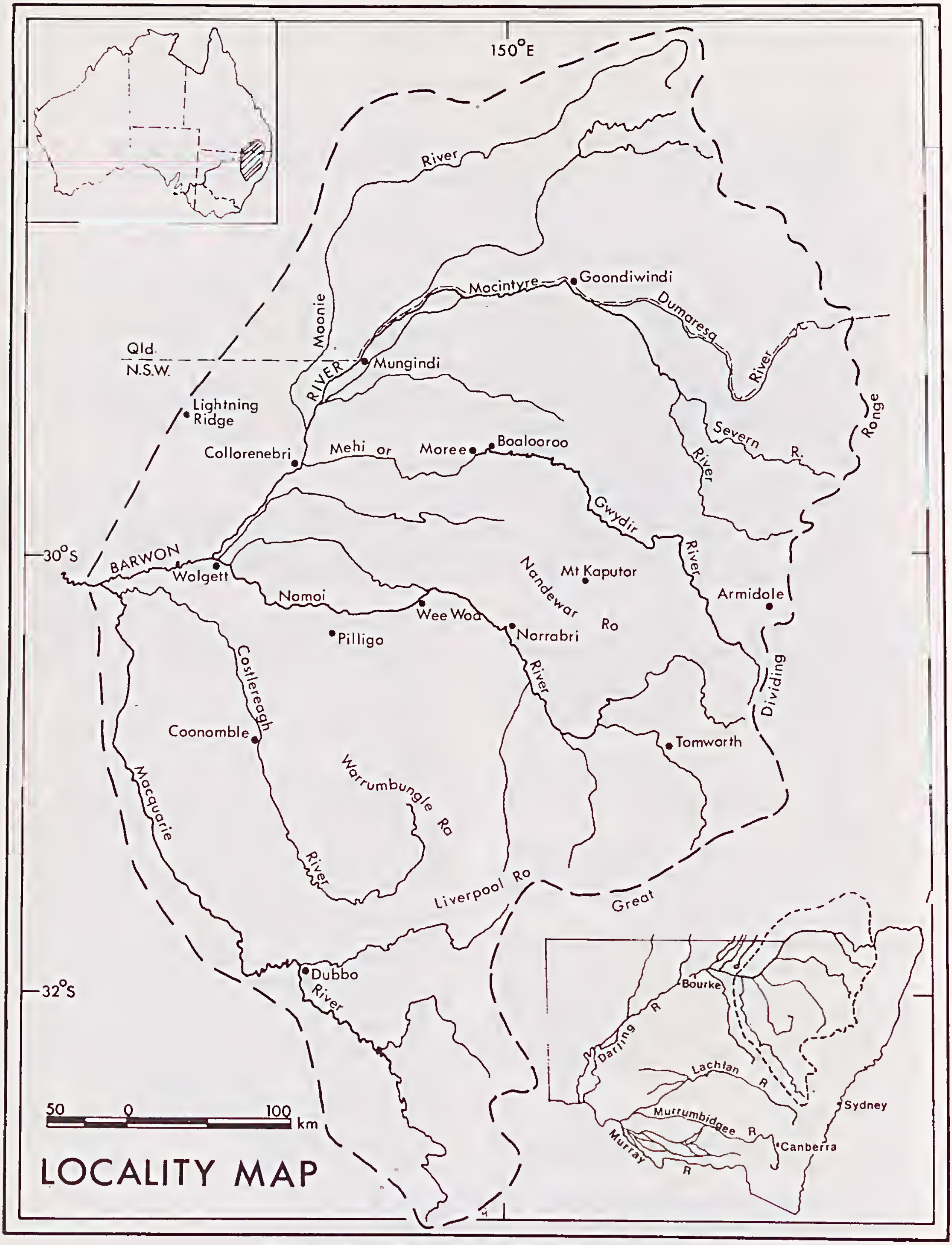

FIG. 1 — A locality map for the Upper Darling Basin.

2. The distributary-dominated, western alluvial plain.
3. The Barwon and Darling river-dominated region.
4. The Pilliga sandplain region.
5. The northwestern Lightning Ridge region of low hill lands.

Each of these will be looked at in greater detail in subsequent discussions.

Details on the climate and hydrology of the Upper Darling Basin are discussed in various Water Resources Commission publications for major streams in the area. It is important to note that towards the west there is a marked decline in runoff per unit area and precipitation and a rapid increase in mean maximum temperature and annual evaporation. The implications of these regional climatic and hydrologic gradients will become evident in the following discussion.

HYDROLOGY

The average discharge for several gauging stations are presented in Table 1. Direct comparisons between the stations are somewhat difficult because they have been operating for different periods and, more importantly, they have not been accurately rated in the upper half (in some cases upper two thirds) of their estimated discharge range. Logistic problems during floods and the interference of numerous distributaries which become active during high stages make it difficult for accurate discharge results to be obtained. Nevertheless, Taylor estimates that approximately 70% of the stream flow from the eastern highland streams actually passes into the Darling. The remainder is lost to groundwater seepage and evapotranspiration across the alluvial plains region (region 2).

Water velocities tend to be remarkably constant along the rivers for flows of similar frequency (Riley 1973). However, there appears to be a downstream decrease in velocity for discharge less than bankfull floods.

Flood hydrographs show considerable attenuation downstream. Consequently, downstream stations tend to receive smaller peak discharges than upstream stations provided no tributaries join between the stations. However, the downstream stations are usually in flood conditions much longer than the upstream stations, with resultant differences in the degree to which sediments (clays) can be dispersed and mobilized and the periods during which floodplain and channel are subject to high shear stresses.

SEDIMENT LOAD

The nature of the sediment load varies downstream and between the tributary streams. The majority of the load comes from the eastern tributaries and directly from the eastern hill lands of the upper third of the catchment.

Distinct differences in sediment load are suggested by the nature of the bed and bank material of the streams. In the east, sands and gravels dominate stream beds, with clearly defined point bar deposits and in-channel bars composed of these textures. Western streams have little sand on their beds, and that which does exist appears to be a thin layer. Unfortunately, no clear distinction can be made between the streams in terms of modes of sediment transport because it is not clear at present whether the clay is transported as flocculated particles of sand-size or as discrete particles less than 2 μm. Riley has noted convex bank deposits that resemble point bars but that are composed of silts and clays. The only detailed sampling of sediment load in the area is that which has been

TABLE 1
DISCHARGE AND GAUGING CHARACTERISTICS OF SELECTED STREAMS IN THE UPPER DARLING RIVER SYSTEM[1]

River Station	*Period record (yrs)*	*Average discharge (M^3/sec)*	*Estimated maximum discharge (M^3/sec)*	*Maximum gauged discharge (m^3/sec)*
Walgett	86	68	1712	642
Brewarrina	43	60	1472	743
Menindie	92	102	2830	689
Bourke	29	121	4075	2550
Wilcannia	86	101	2745	560

[1]*From Water Resources Commission of N.S.W.*

PLATE 9A
LANDSAT photo, Band 5, of 27th August, 1972 of the Gwydir distributary system.

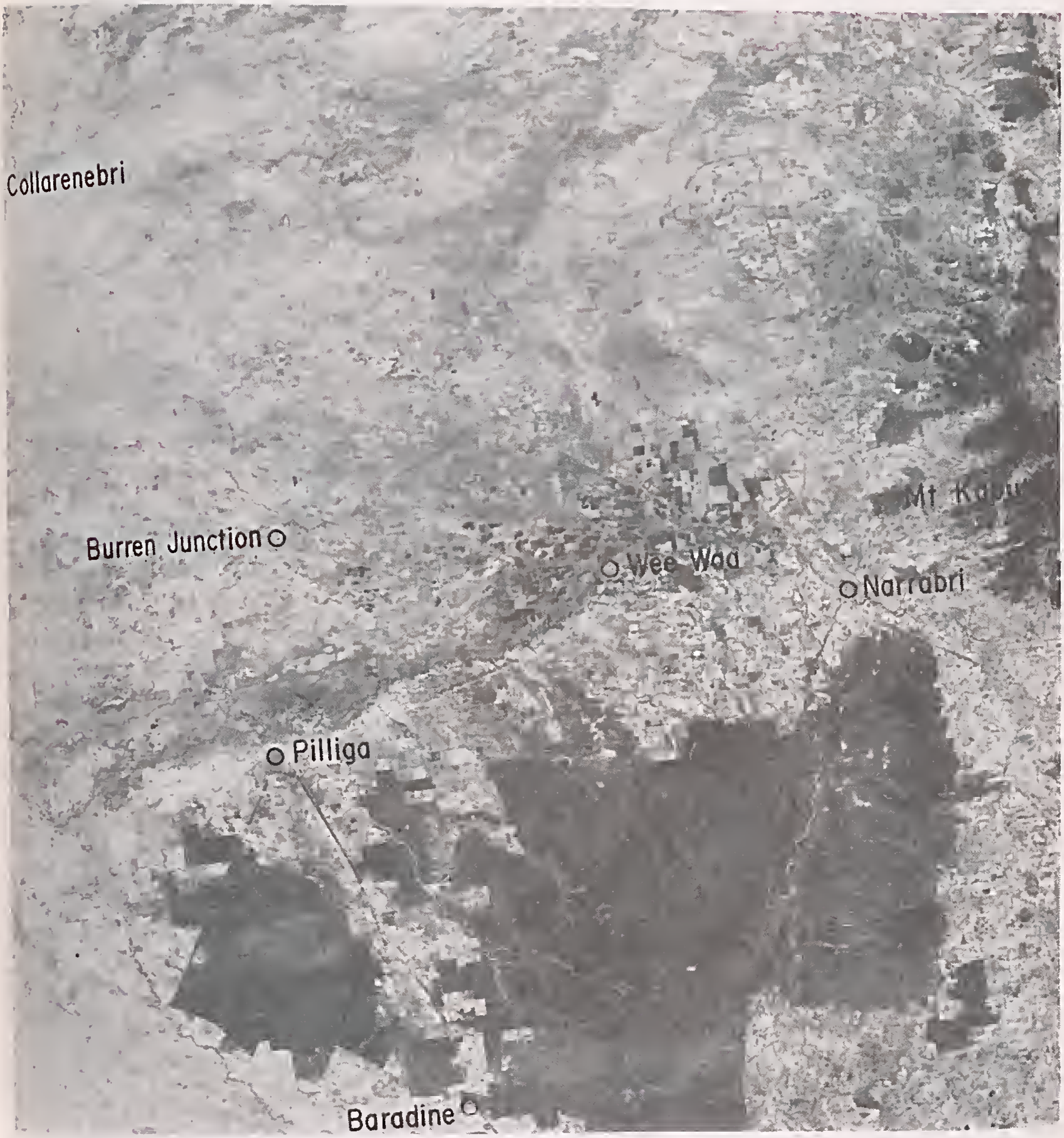

PLATE 9B
LANDSAT photo, Band 5, of 18th January, 1973, of the Namoi distributary system, Pilliga Sand Plain, and interaction zone between Namoi and Gwydir distributary systems.

conducted by Woodyer and Taylor (see Woodyer *et al.* 1977).

The relation between sediment concentration peaks and discharge are complex. At Walgett, of an annual sediment discharge of 500,000 tonnes 95% is washload, of which 80% is montmorillonite clay. The washload sediment concentration peak is preceded by the flood wave in the case of within-bank floods, but precedes the flood peak in the case of overbank floods (Woodyer 1978).

As stage increases the amount of bed-load and suspended-load appears to increase. However, the total suspended-load is small, as no sand has been sampled in suspension and it must be rapidly deposited out along the channel.

Taylor (1976) estimates from the Langbein and Schumm (1958) curves and subsequent modifications that 8×10^6 tonnes per annum of sediment are transported in the Upper Darling system, but that only 5×10^5 tonnes per annum pass through the Barwon at Walgett. Thus it appears that 7.5×10^6 tonnes of sediment per annum are deposited over the western alluvial plain or trapped in the low-order tributary valleys of the eastern hill lands. However it must be remembered that the estimated value is subject to error. We estimate that the dissolved-load is of the same order, and probably greater than the particulate load.

REGIONAL DEPOSITION

There is evidence that the bed material load transported from the eastern hill lands is largely deposited at the eastern edge of the western plain. The deposits take the form of large, low-angle alluvial fans and exhibit many of the morphological properties of fans (Wasson 1974 and pers. comm.). The evidence for deposition is:

1. The distinct change in morphology of some of the westward-flowing streams as they traverse the plains. Many which have wide sand beds or clearly-defined sand ripple and line features in the east do not have these features in the west.
2. There is a general westward decline in the proportion of sand in stream beds and in the median grain-size of bed sediments (Riley 1977).
3. Numerous distributing channels pass through swamps which would trap all but the finest of sediment.
4. LANDSAT imagery suggests that deposition in the form of alluvial fans is occurring (Pl. 9).
5. There is ample evidence from local farmers around Moree that the terminus of the Gwydir has been an area of considerable aggradation (reports of fences and stock yards being buried in periods of 20 to 40 years).

There is, however, some evidence to suggest that the aggradation is not great over the long term, and that it is very localized. This evidence is:

1. The thickness of the western plain alluvial deposits suggest rates of aggradation of the order of 2×10^{-2} mm/yr for the whole of the Namoi and Gwydir fans but these are probably at present of an order of magnitude less.
2. There is no conclusive evidence that bed loads of coarse sand and gravels are being transported along the Gwydir and Namoi Rivers at high rates. Riley (1973) notes that the median grain-size for the terminus of the Gwydir is in the silt and fine sand fraction and not the gravel that is exposed farther upstream of Boolooroo.

For the Namoi and Gwydir the real situation is probably one of localized deposition at the point where distributary offtakes are most prevalent and of uniform transport rates and low sedimentation rates across the alluvial plain. For the Macquarie and Castlereagh Rivers the situation is somewhat different, as they appear to drain areas which deliver large amounts of sediment to the streams. The wide sandy bed of the Castlereagh contrasts markedly with the beds of the Namoi, Gwydir, and even Maquarie Rivers.

STREAM MORPHOLOGY

There are significant morphological differences between the distributaries and parent streams of the western plains (Riley 1973). These differences are a result of differences in frequency of flow and sediment loads transported by the respective channel systems.

Distributaries are by no means stationary systems. At any one point in time some streams are expanding at the expense of others in the system. This temporal variation is illustrated in the Gwydir system by the Mehi, which seems to be in the process of capturing the lower end of the Gwydir River channel. A consequence of the transient nature of the channel system is that many features observed in the system may be a result of temporal change rather than spatial change. Unfortunately, because the rates of change for the area are not known, it is impossible at present to separate spatial and temporal effects. Thus, to label as relict any stream in the distributary system which transports water and sediment is to relegate it to a position that may not be warranted in the dynamics of the system.

Taylor (1976) thought that, for anabranching distributaries near Walgett, the morphology of the streams suggest channels that transported much greater suspended loads and discharge than does

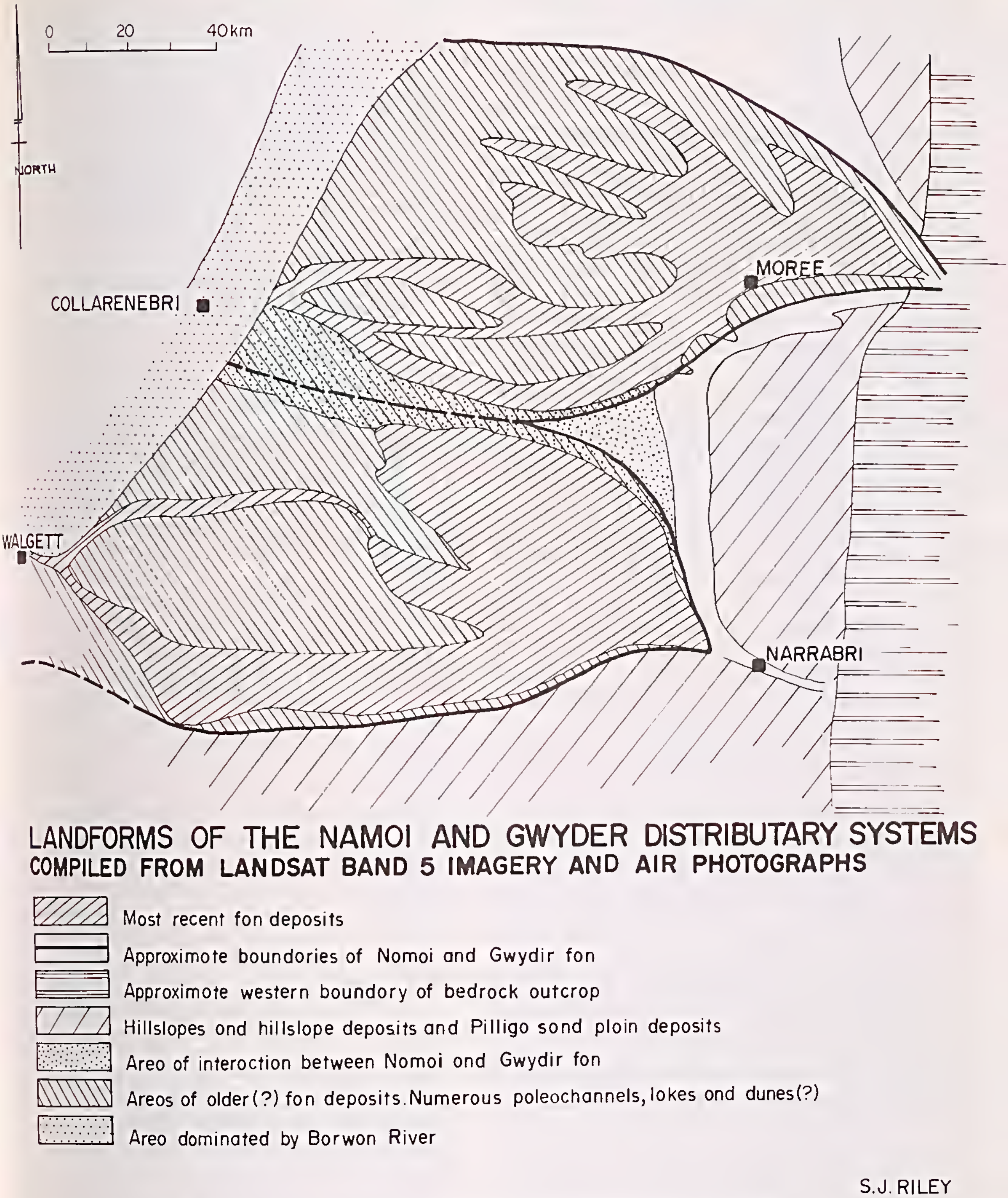

FIG. 2 — A geomorphic map of the Namoi-Gwydir distributary system.

the present Barwon-Darling system. That is, there is a clearly defined palaeochannel system suggesting discharge regimes different from those of today.

GENERAL REGIONAL GEOMORPHOLOGY

Eastern Hill Lands Region

There is a distinct north-south oriented demarcation line east of Narrabri and Moree that separates the eastern hill lands from the western distributary areas. This line is marked by a belt of folding and faulting and degraded volcanic landforms, and is best defined in the vicinity of Mount Kaputa. East of the line are bedrock exposures, west are the alluvial deposits. The line is less well defined in the south, but nevertheless there is a distinct transition along the Castlereagh and Macquarie Rivers.

The highest points in the landscape are occupied by the Tertiary Volcanics (e.g. Nandewar, Liverpool and Warrumbungle Ranges).

Many of the lower-order streams appear to be aligned with the general dips and strikes. However, larger streams traverse the general structural trends. General stripping of large areas of Tertiary basalt cover and the discordance between major stream alignment and structure suggest that at least some of the larger streams are superimposed. The drainage pattern as a whole is dendritic.

Slopes are greatest in the vicinity of the basalt highlands on the eastern and southern margins and are of the order of 15° and greater. There is a marked westward increase in valley widths and decrease in valley side slopes towards the west.

The large number of interfluves that are marked by Tertiary volcanics would suggest that there was some disorganization of the regional drainage as a result of Tertiary volcanic events. Occupation of valleys with basalts and inversion of relief (e.g. Mount Panorama) support this suggestion. The effect on the Upper Darling Basin of the tectonic events is as yet not fully explained (Wellman 1971).

A large number of streams exhibit terraces, but at present there is no clear picture of the sequence of erosional/depositional events along the streams. Perhaps the historical sequence that has been defined by Warner (1967) for the Bellinger and other coastal rivers may have implications for the upper reaches of the Namoi and Gwydir Rivers. The area was probably influenced by periglacial and nivational action during the Quaternary (Galloway 1965, Bowler *et al.* 1976) but, again, the significance of the Quaternary climatic fluctuations on the basin is undefined.

Western Distributary Plain

This region is dominated by an extensive alluvial plain with an associated distributary system. The region is a large scale alluvial fan complex with apexes at the point where the streams traverse the eastern hill land margin.

LANDSAT photographs (Pl. 9) of the Namoi and Gwydir region suggest three sub-areas, namely: 1. the area of most recent stream activity and fluvial deposits; 2. older (Pleistocene?) areas of alluvial deposits; 3. an area of interaction between the Namoi and Gwydir fans.

The most recent fluvial deposits are montmorillonite-rich black clay soils, derived chiefly from the basalts of the east (Corbett 1965, Isbell 1957). The soils have considerable swelling and shrinking capacities.

Stringers of sand and gravel throughout the area suggest considerable alteration of stream courses as well as streams with sediment transport characteristics different from those of today.

The channel pattern over the whole area is a distributary system (Riley 1975). The causes of distributary and fan development are not clearly understood. However, the rapid decline in mean annual flood discharge towards the west and the rapid change in slope from the eastern hill lands to the plain suggest that the fan and channel patterns are a response to changes in energy regime in the streams.

Most of the streams emerge onto the plains of the Upper Darling Basin as wide, shallow channels. These channels are dominated by bed-load; they meander or are braided and, as with the Castlereagh River at Coonamble, are frequently bounded by large levee banks. They are typically straight to moderately sinuous with sinuosites varying from 1.1 to 1.8. These channels do shift laterally and the region between the Macquarie and Namoi Rivers is covered by remnants of wide shallow beds as mixed-load channels. Many of these still flow.

In the east of the Basin these mixed-load channels do not extend out onto the plain further than Moree or Wee Waa (Pl. 9). However, further south they extend 100 km or so out across the plains. At the downstream end of such a wide shallow channel the channel divides into numerous small distributaries as on the Castlereagh, Macquarie and Gwydir. These distributary networks are series of channels of ever-decreasing size which eventually terminate in a swamp on the alluvial plain (Pl. 10, above). The streams continue on the downstream side of these distributary

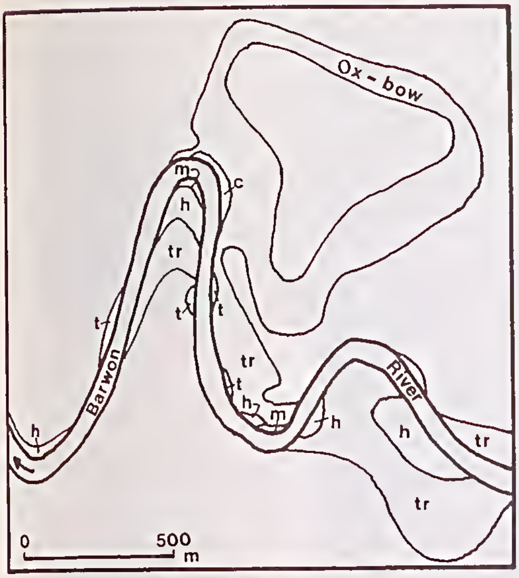

FIG.3 — A plan of the benches along the Barwon River near Walgett. Note the development of benches at the bend and also on the outside of the bend as well as along the straight reaches. Terrace (Tr), high bench (h), middle bench (m), ti-tree bench (t), and concave bank bench (c).

networks as deep, narrow, highly sinuous, suspended-load channels which contain virtually no bed-load. These streams are similar in morphology and the nature of their deposits throughout the rest of the downstream segment of the Basin.

The Darling-Barwon Region

The western extremity of the basin is an area of interaction between the Barwon River, which is base level for the whole basin, and the several distributary and parent streams. The Barwon truncates the distal end of the Namoi and Gwydir fans (Fig. 2).

The region is dominated by numerous cutoffs and distributary channels oriented towards the south and parallel to the Barwon. There are numerous palaeo- and present-day ephemeral lakes in the area.

Backwater effects from the Barwon no doubt have considerable effects on the lower reaches of the eastern tributaries. With the latter rivers having bedslopes in the order of 10^{-4}, small rises of only 5 m in the Barwon can be transmitted up to 50 km upstream in the westward-flowing channels. The nature of these effects is not clear, except that stream flows and consequent sediment depositional trends can be reversed.

Channel Morphology of the Suspended-Load Streams: In general, the suspended-load streams are deep, narrow, highly sinuous and have steep banks with a series of depositional benches developed on them. The Barwon River at Walgett has a width:depth ratio of 8 with a mean sinosity of 2.3. The bed gradient averages 5×10^{-5} in the Darling downstream of Walgett. Bank slopes average 26° but often exceed 40°, even at depositional sites. Benches form the most prominent morphological feature aside from the narrow deep channel. Benches occur commonly at three levels (Fig. 3) along the channel: low, halfway up, and near the top of the bank (Taylor 1976, Woodyer 1968, Riley 1973, Woodyer *et al.* 1977). The benches are depositional channel features, flat, elongate and often crescentic in plan (Fig. 3). They develop at various sites along the channel, most commonly at the insides of bends as point benches, along straight reaches as straight reach or ti-tree benches, or, and less commonly, along the outside of bends as concave bank benches (Woodyer 1975). Along the Barwon near Walgett the higher two benches are very common and form a distinct and mappable surface bordering the channel (the high bench is the present floodplain of the Barwon River).

Along much of the Upper Darling and some of the suspended-load tributaries the channel is also bounded by a terrace above the high bench (Pl. 10, below). This terrace is a relic of a former regime and, although morphologically similar to the benches, is composed of entirely different sediments.

The suspended-load streams, although highly sinuous, appear to be relatively stable. The Barwon River at Walgett, for example, has not shifted its course significantly in the last 100 years (Taylor 1976). There is virtually no erosion at the outside of bends: in fact some concave bank benches are aggrading.

Deposition in the suspended-load segments of the streams is characterized by mud deposited from suspension. Taylor (1976) has reported in detail on the nature of deposits along the Barwon River near Walgett. The majority of deposition in the Barwon occurs along the banks on benches, although during major floods deposition also occurs on the terrace and across the regional alluvial plains.

Benches develop along the banks on a basal deposit or footing. These vary depending on the site along the river. At bends the footing is a point deposit of cross-bedded sands (Pl. 11, above) overlain by thin mud beds which represent mud slopes left on the flood recession. These mud beds

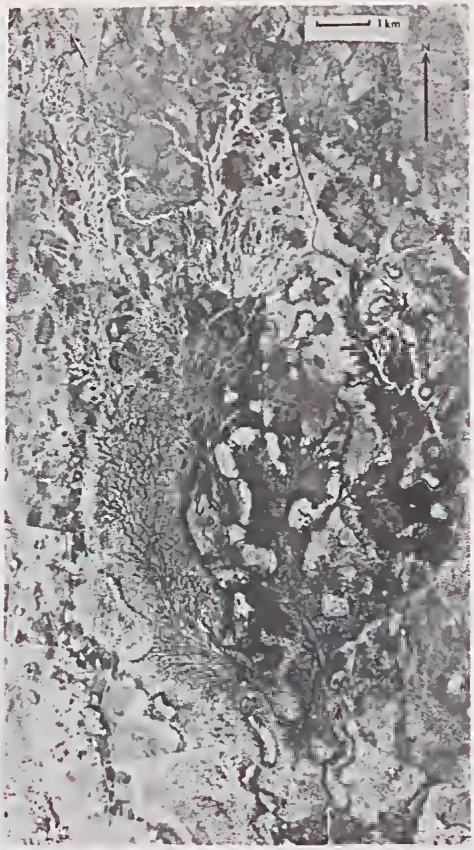

PLATE 10

(Above) A distributory marsh on Nedgera Creek between the Macquarie and Castlereagh Rivers. The flow is towards the north, the channel entering the marsh is sandy and that leaving it is muddy.

(Below) Photograph of a sequence of point benches on the Barwon River near Walgett. The lower level (Wn) is the middle bench, the intermediate level (D) is the high bench and the top level (V) is the terrace. The low sandy bench is covered by water.

PLATE 11

(Above) Shows the same sequence of levels at another point along the Barwon near Walgett except that the low sandy point deposit (P) is illustrated. Other legend as for Pl. 10, below. Wg is the regional plain surface.

(Below) Ti-trees growing low in the channel and providing a screen behind which sedimentation occurs, gradually killing the trees and forming a ti-tree bench.

FIG. 4 — A generalized vertical profile through the bench deposits of the Barwon River.

increase in frequency up the point sand until typical bench deposits form. The height to which cross-bedded sands can be deposited is limited by the height of bedload movement. Along straight reaches and on the concave bank of bends bench footings are developed in two ways: firstly, by bank collapse resulting in a low-level mud being formed within the channel; secondly, ti-trees grow low in the channel and these tend to trap, around and behind them, sediment which provides the base for further bench development (Pl. 11, below).

The bench sediments are a sequence of interbedded thin sand and mud beds (Fig. 4) which are usually flat but may also be wavy. They are frequently graded and reverse-graded and lack erosional contacts. There is virtually no cross-bedding. The beds are deposited from suspension on both the top and front of the bench, producing vertically and laterally accreting, lenticular, sediment bodies along the banks of the streams. Due to the cohesive nature of the sediments deposited they suffer virtually no erosion during subsequent floods.

The continued deposition on benches causes a restriction of the channel which ultimately leads to a damming of the stream and evulsion, forming a new channel. This process is one of the major factors responsible for the large number of anabranches typical of the Darling and its tributaries in their suspended-load phases. Many of these anabranches are still developing their channels and many others are no longer active.

The Barwon at Walgett and many of the ancient suspended-load anabranches in the region have an ancestral channel associated with them. These channels deposited dominantly sandy point bars with typical scroll-bars. There is morphological evidence to suggest that the sandy ancestors and former suspended-load streams formed under different climatic conditions from those at present;

however, the sandy ancestors do not consistently show evidence of climatic control as seems to be the case in the Murray-Murrumbidgee System to the south (Schumm 1968, Bowler 1967, Bowler *et al.* 1976, Butler 1960, Pels 1964 a,b, and 1966, Langford-Smith 1960). One of us (G.T.) considers that the newly formed channels develop through a mixed-load phase prior to regressing to suspended-load deposition (Woodyer *et al.* 1977). While not denying climate change as a factor in the evolution of the Upper Darling, he suggests that evulsion and channel development due to the sedimentary processes in those channel complexes are the primary causes of channel shifting. Climate change may change the rate of development of the system and the gross channel morphology to some extent, but because of the cohesive nature of the sediment and the low gradients, the depositional character of the system is the major control.

Pilliga Sand Plain

The Jurassic sandstone area of the southern Namoi basin dominates the surface material and morphology of a region between Pilliga and the Warrumbungles. The region has a relief of approximately 500 m and slopes uniformly down towards the northwest.

The stream pattern is dendritic. Unlike streams of the distributary area which on the whole have cohesive beds, the streams of the Pilliga region are wide and sand-bedded. The peculiar sandy nature of the Castlereagh is a result of its headwaters being in this area.

The sand from the Jurassic sandstones appears to have covered a large area of the southern distributary plain and the deposits from the two sources interfinger. The Namoi west of Wee Waa is being fed by several sand bed streams from the Pilliga region.

The Lightning Ridge Region

This area is largely composed of low hill lands and has extensive areas of bedrock outcrop covered in part by silcretes and late Miocene sheet gravels (see Taylor 1978).

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